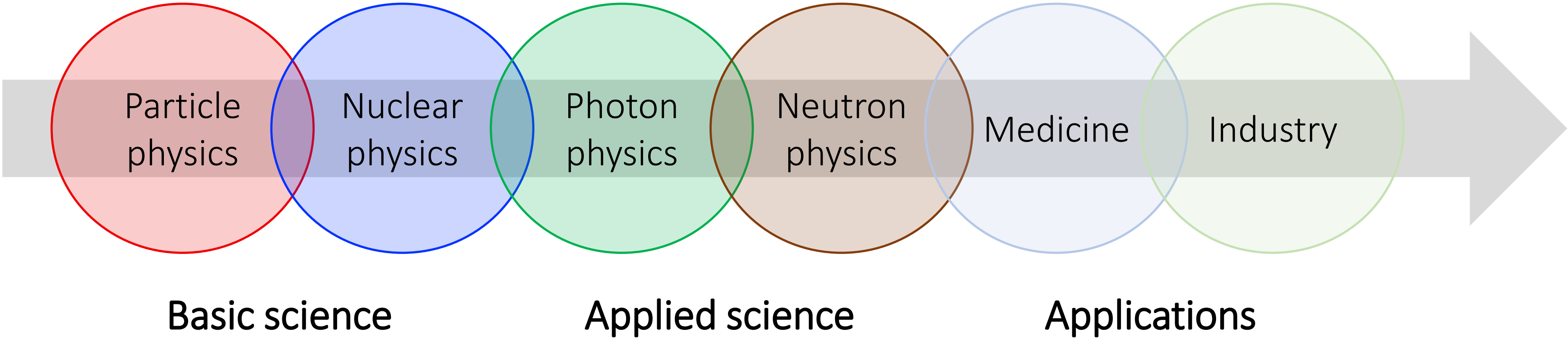
# *Accelerator Projects in Europe*

Edda Gschwendtner, CERN

IPAC2024, Nashville, Tennessee, USA

# Particle Accelerators

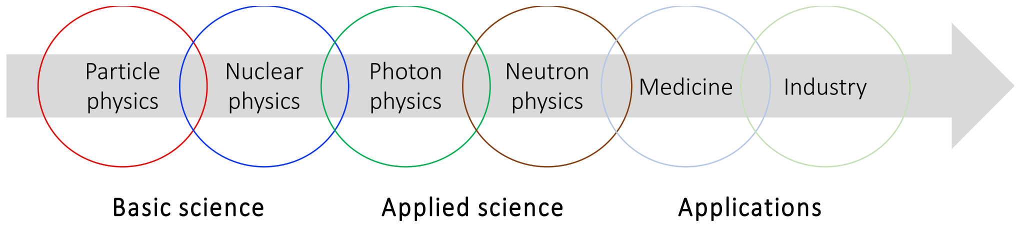
- Particle accelerators are sophisticated instruments used in a wide range of domains, from **basic science** to **applied science** to **medicine and industry**.
- Traditionally, the **strongest demands in terms of technologies and performance are coming from particle physics,** from which new technologies extend to other applications and finally reach the society.



# Outline of this Talk

1. Accelerator projects overview in Europe

2. Examples from the three accelerator domains




3. Lessons learnt from HiLumi-LHC

# Regional Accelerator Projects in Europe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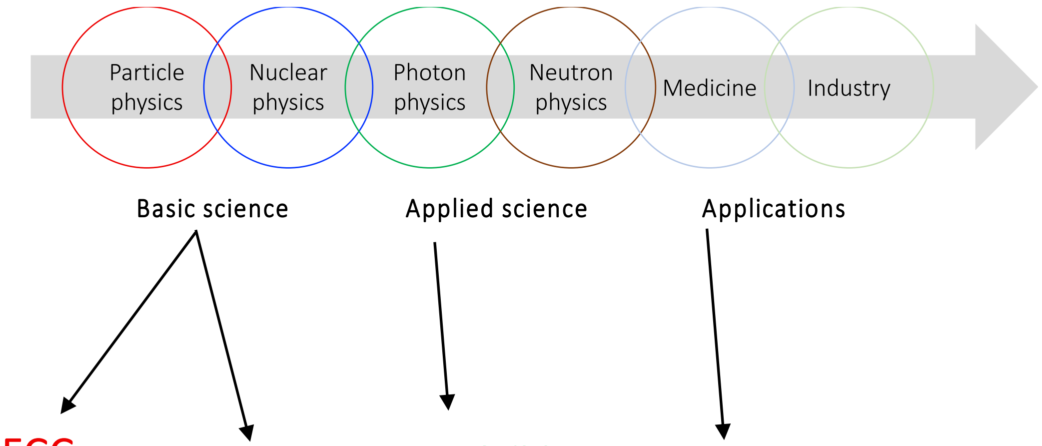
# Regional Accelerator Projects in Europe




FCC
PERLE

FAIR

PETRA IV
*EuPRAXIA*

*FLASHDEEP*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**Project Region: EMEA**



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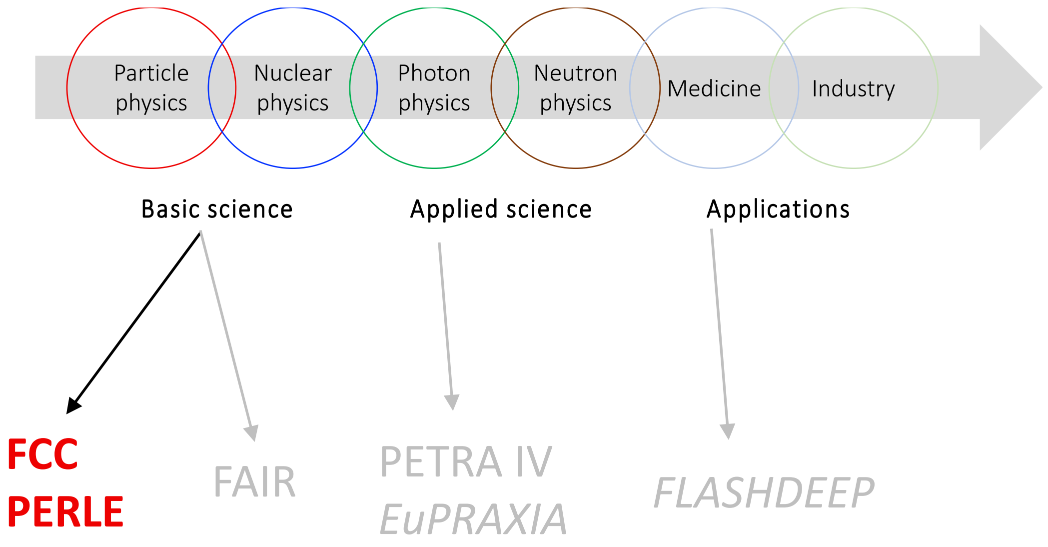
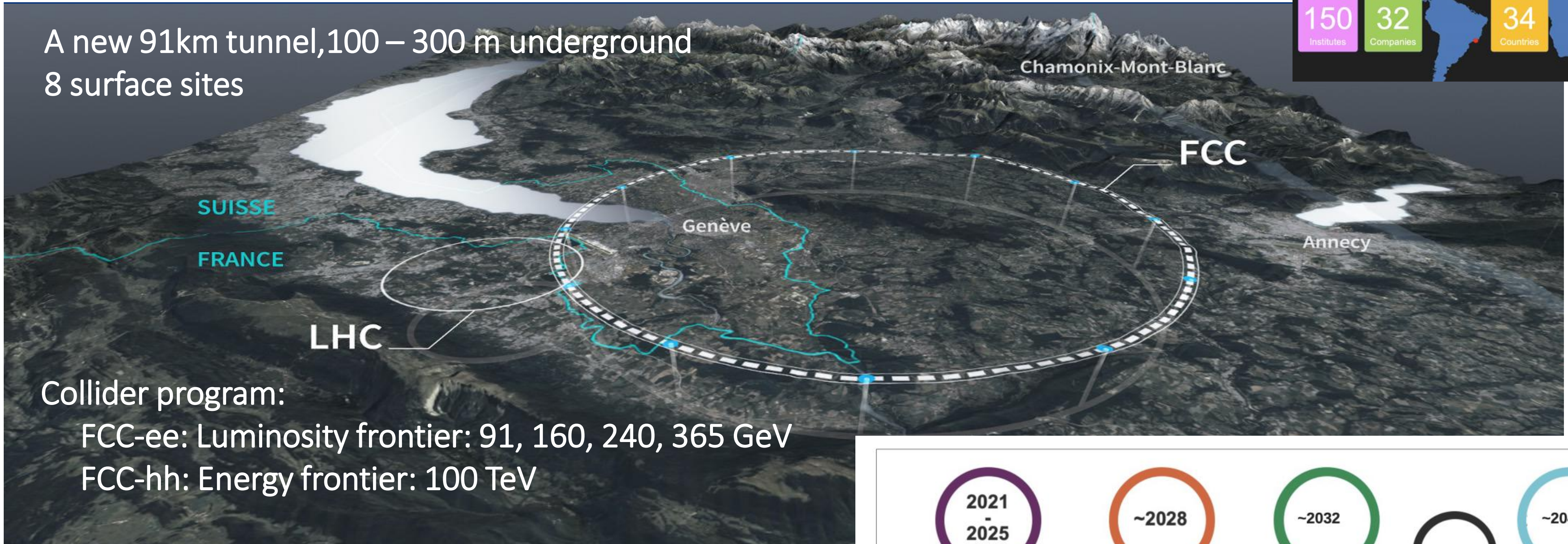
2. Examples from the three accelerator domains




3. Lessons learnt from HiLumi-LHC

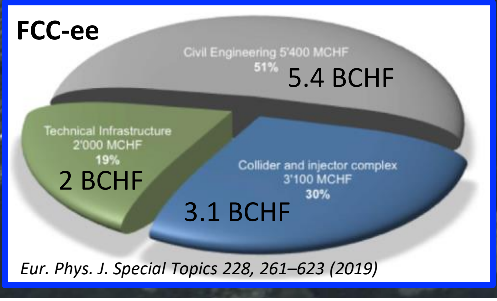
# Future Circular Collider, FCC

Inspired by successful LEP – LHC program at CERN
Comprehensive long-term program maximizing physics opportunities

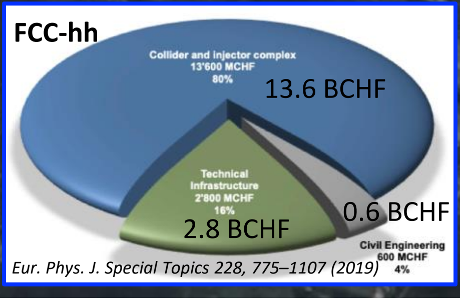




A new 91km tunnel,100 – 300 m underground
8 surface sites

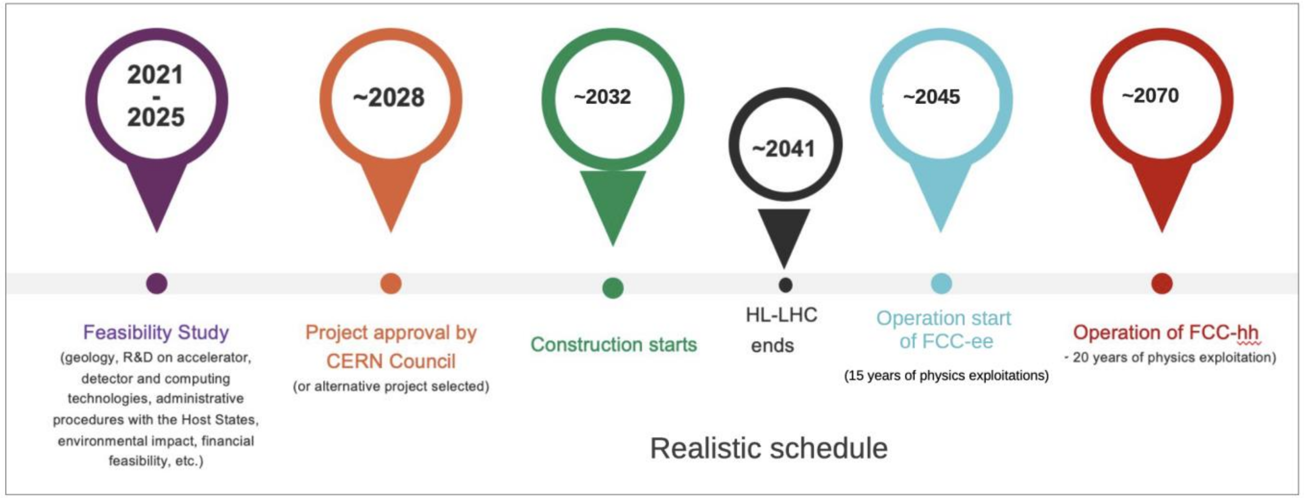
Collider program:
- FCC-ee: Luminosity frontier: 91, 160, 240, 365 GeV
- FCC-hh: Energy frontier: 100 TeV




*Eur. Phys. J. Special Topics 228, 261–623 (2019)*



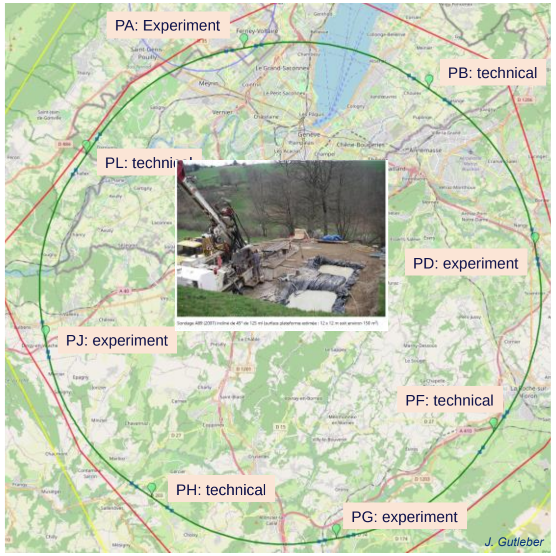

*Eur. Phys. J. Special Topics 228, 775–1107 (2019)*




E. Gschwendtner, CERN

# Future Circular Collider, FCC, 3 Key Challenges

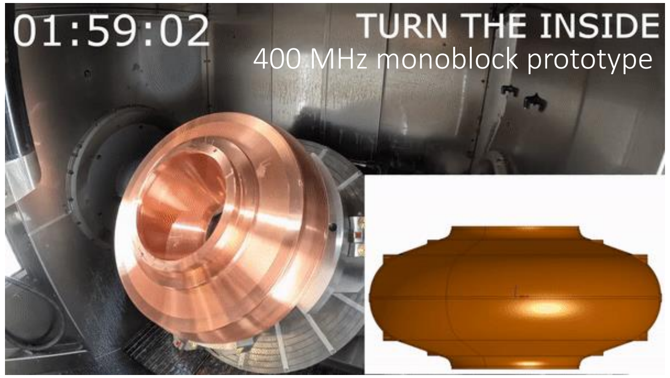
## Civil engineering:
## 91 km long tunnel




**Industrial needs:**

- Low-cost **excavation&tunneling technologies**.
- Local low **carbon concrete production**.
- Near-real time **materials separation**.
- Excavated **materials re-use** development.
- Transformation into **fertile soil**.
- **Low-carbon construction materials.**
- Modular **low noise processing** facilities.
- **Eco-friendly water treatment** systems.
- **Waste heat recovery** technologies.

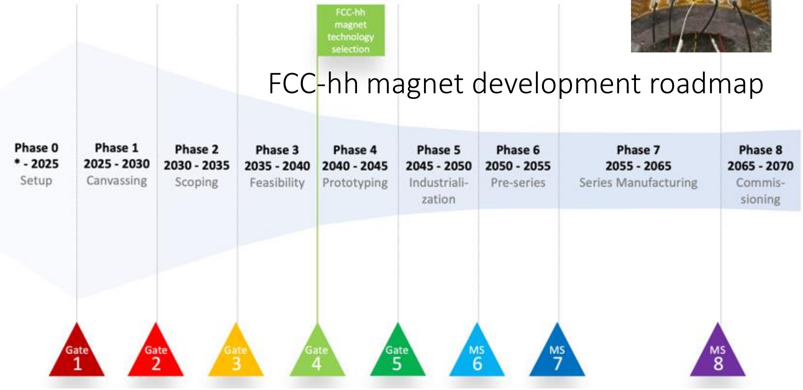
## FCC-ee:
## 50 MW synchrotron radiation/beam
## → Optimized RF system to increase energy efficiency




**Industrial needs:**

- **Efficiency above 80%** of commercially available **klystrons** (TRL).
- **Cryogenic refrigeration plants** with increased energy efficiency.
- **Support for dynamically changing operation needs** at 2 K (for superfluid He with 800 MHz RF) and 4.5 K (400 MHz RF).
- Advance **MW scalable high-power solid state amplifier** systems and **smaller space footprint** requirements.

## FCC-hh:
## 100 TeV c.o.m.
## → high-field superconducting magnets, 14 – 20 T.
## → Technologies: $Nb_3Sn$, HTS




FCC-hh magnet development roadmap

**Industrial needs:**

Magnet and tooling components are procured with an expected cost over 5 years of **15 MCHF** for Low Temp. Superconductors and **2 MCHF** for HTS.

- **The "Prototyping" and "Industrialization" phases will see a ramp up of industrial involvement, in view of an eventual large-scale production.**

# PERLE – Powerful Energy Recovery Linac for Experiments

→ Demonstrate readiness of all Energy Recovery Linacs aspects for HEP colliders
Multi-turn ERL based on SRF technology (3-turns, 500 MeV electrons, 20mA)

**International Collaboration at IJCLab (Orsay/Paris, France)**
**Budget: 21MEuros (1-turn) + ~5MEuros (2 extra turns).**
Implementation has started
2028: First stage: one-turn and 1-cryomodule (pending some budget requests)

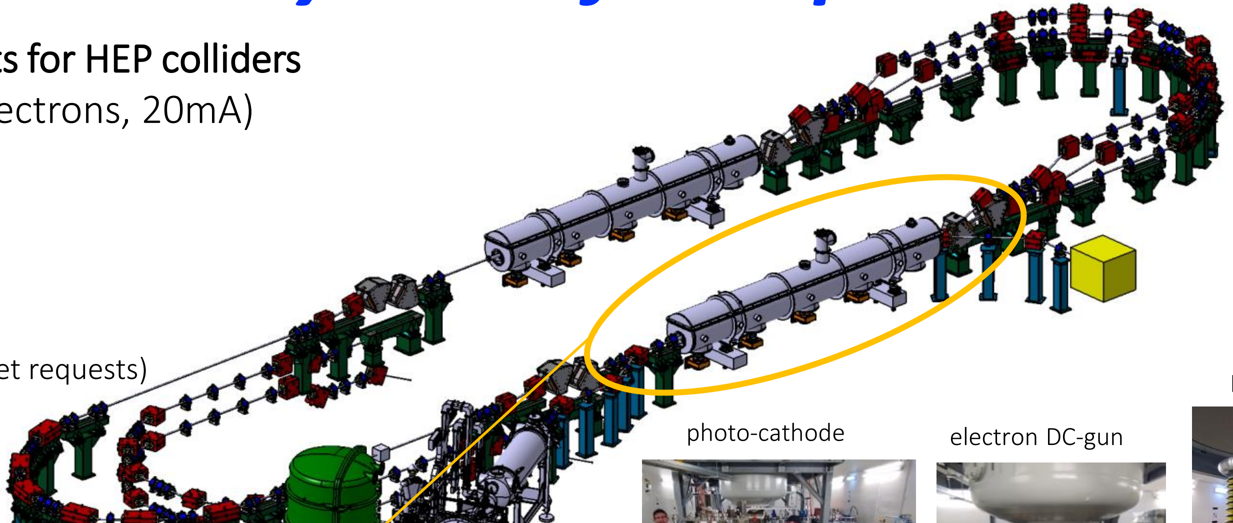
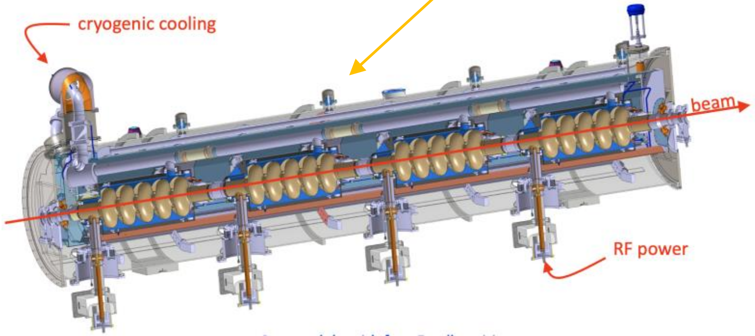


photo-cathode

electron DC-gun

HV tanks

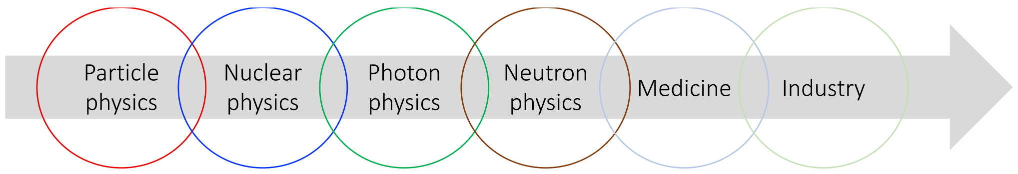
**iSAS project:** 1st cryomodule developed within "innovate for Sustainable Accelerating Systems".
**EU funded project: 13 MEuros, 2024-2028.**
→ Improve energy-efficiency of SRF cryomodule
→ **Co-developments with industry to increase the TRL towards large-scale deployment**




Industrial needs:
- **Higher-Order Mode** Damping
- **High-Temperature** SC Technology (→ 4.2K)
- **Fast Reactive Tuners** & RF power source
- **Magnets, lasers, cryogenics, diagnostics,…**

1. Accelerator overview in Europe

2. Examples from the three accelerator domains




Basic science — Applied science — Applications

**FCC**
**PERLE**

**FAIR**

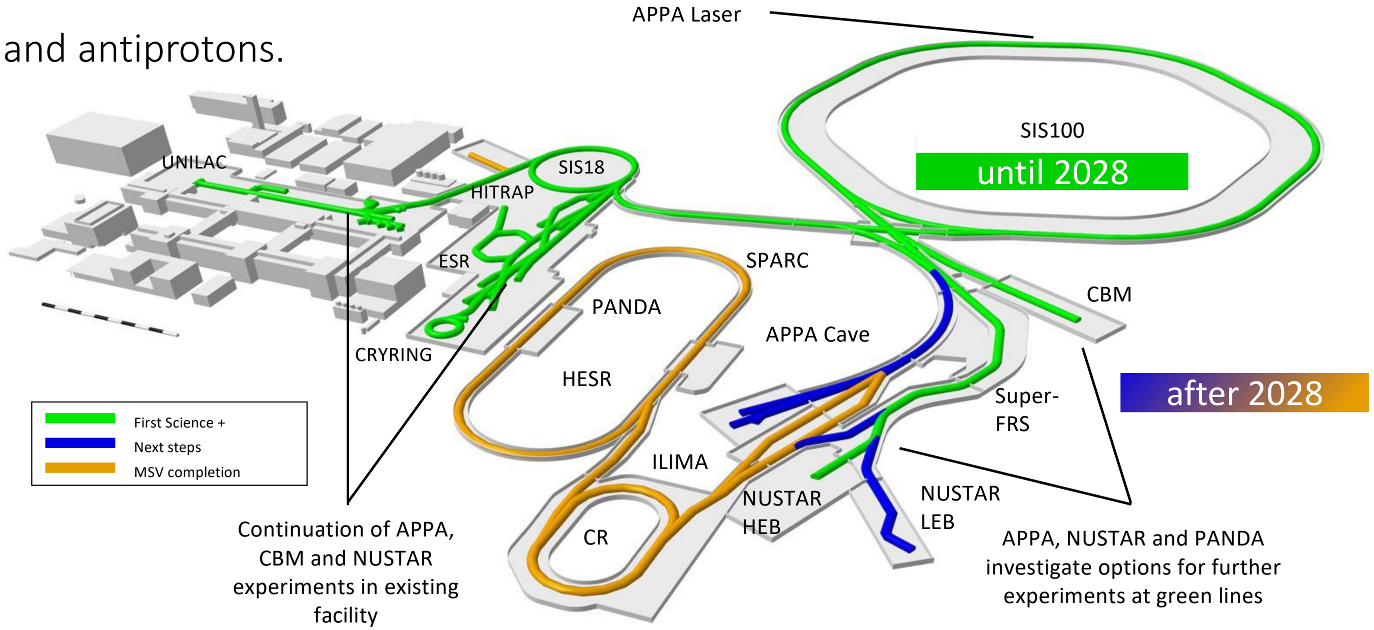
PETRA IV
*EuPRAXIA*

*FLASHDEEP*

3. Lessons learnt from HiLumi-LHC

# FAIR, Facility for Antiproton and Ion Research in Europe

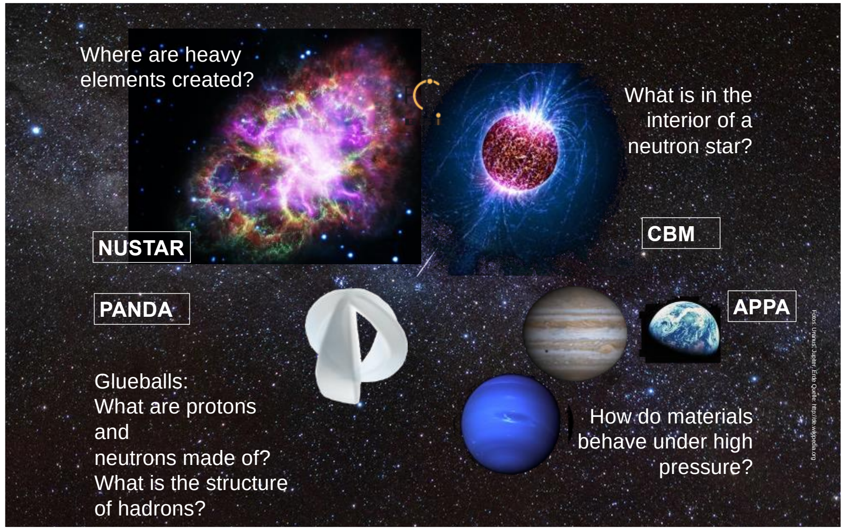
Study the structure of matter and the evolution of the universe.
→ Provide particle beams of all the chemical elements, their ions and antiprotons.




## GSI Darmstadt, Germany
## Budget: 3.3 BEuros

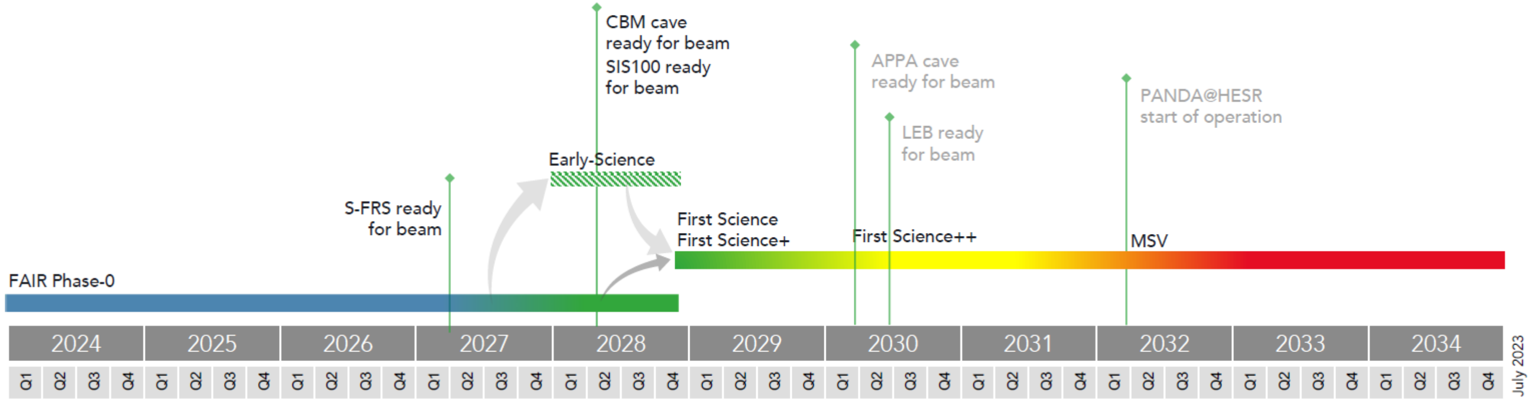

Nuclear structure, Astro-physics and Reactions

Compressed Baryonic Matter

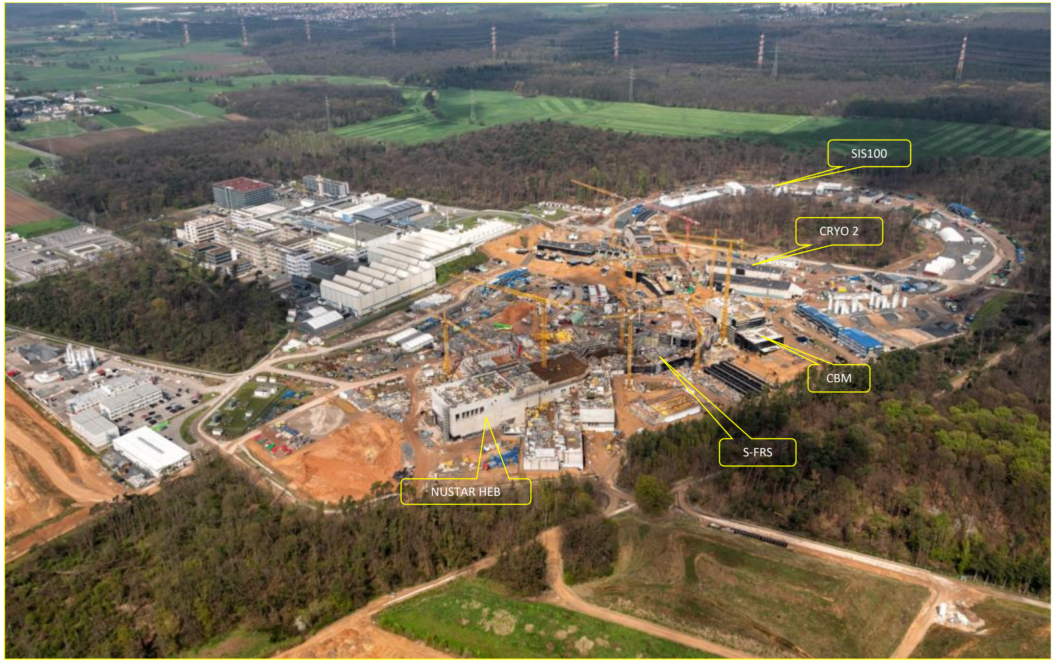



AntiProton Annihilation at DArmstadt

Atomic, Plasma Physics and Applications



# FAIR, Facility for Antiproton and Ion Research in Europe




Remaining Procurement volume:
**First Science 80 MEuros until 2027**
**MSV 150-200 MEuros from 2027 onwards**

First magnet installations in tunnel

Helium tanks of cryo facility installed


Industrial needs:

- **Cryogenics**, **vacuum** and leak detection technologies
- **Diagnostics** and detectors, sensors, optics and instruments
- Electrical power **electronics**,
- Electromechanical and **RF systems**
- **High precision** and large mechanical components
- **Instrumentation**, **control** and CODAC
- Superconductivity and **superconducting** magnets
- **Normal conducting magnets**
- **Remote handling**

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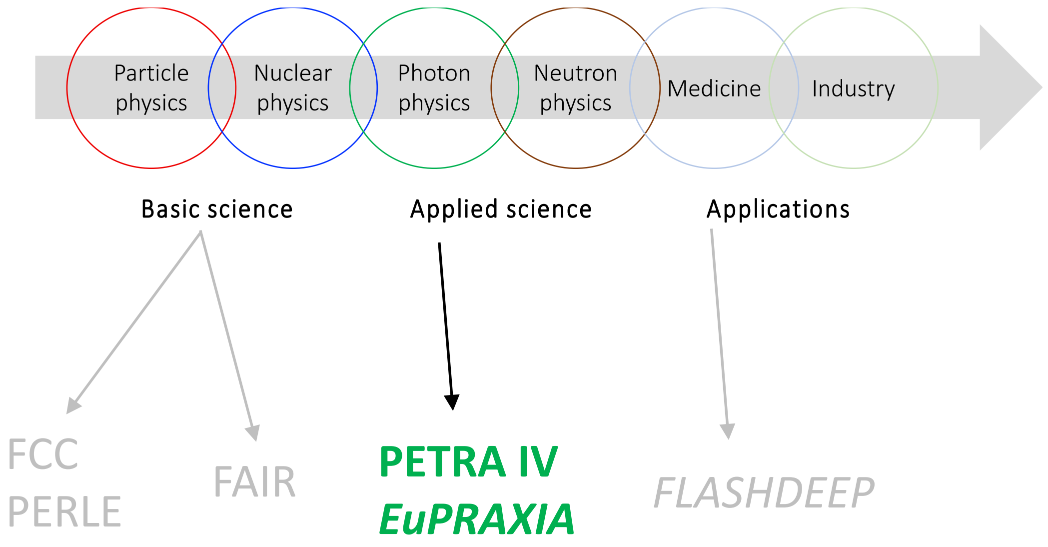


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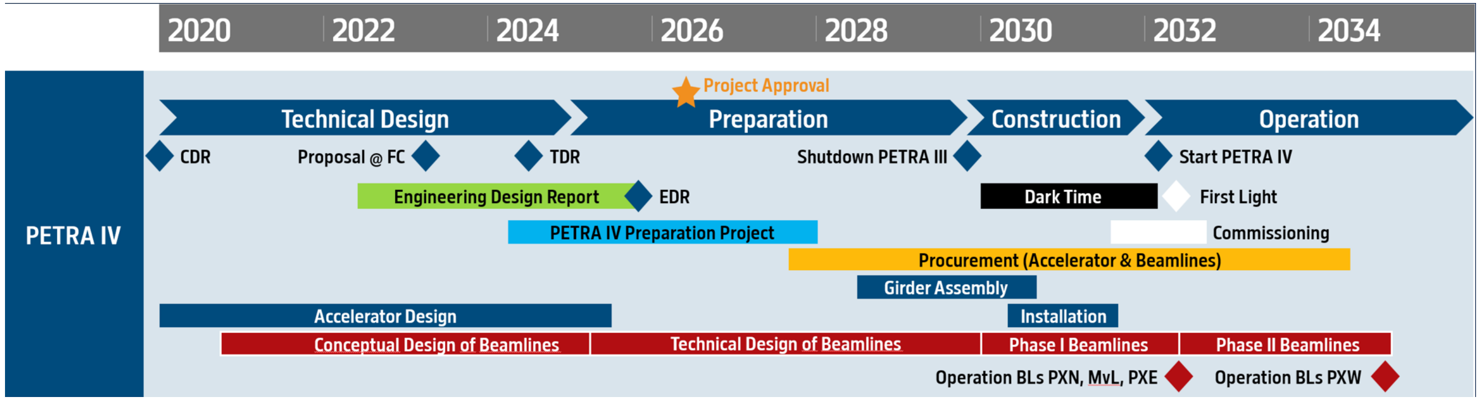
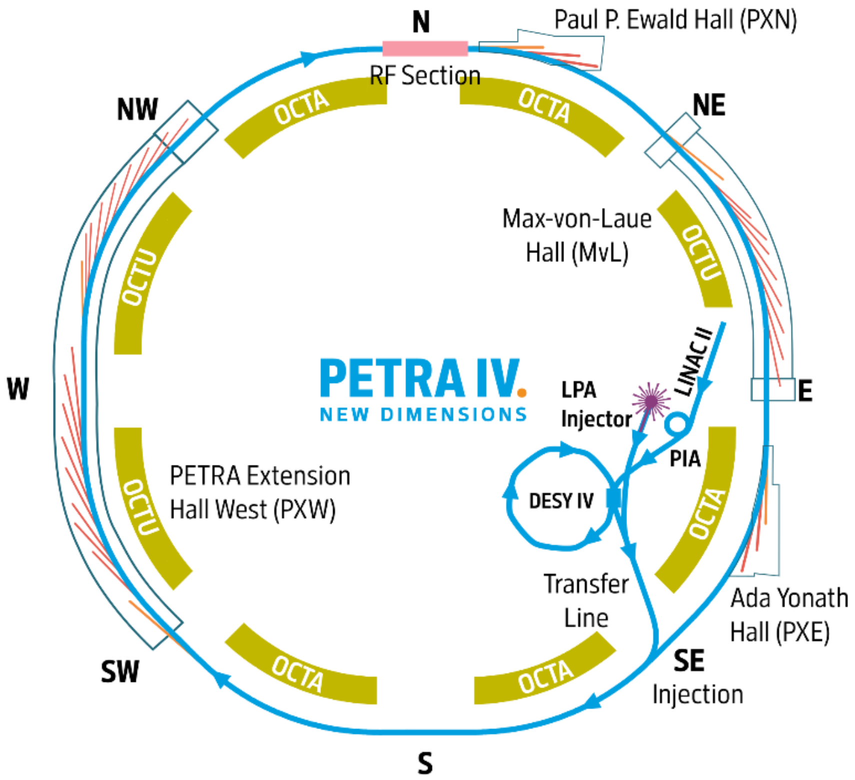
# PETRA-IV

**DESY/Hamburg**
**Budget: 1.5 BEuros**

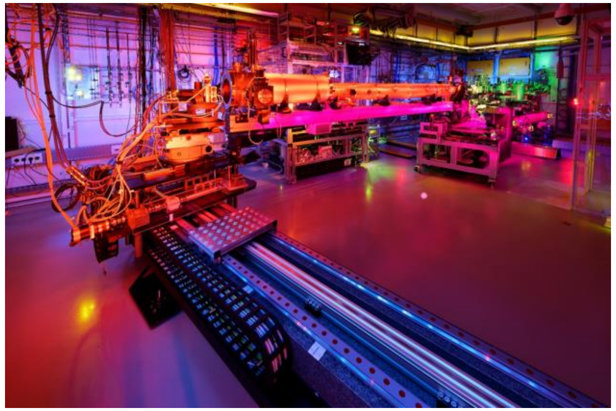



**4th generation SR source:**

→ Extension/refurbishment of the existing PETRA III infrastructure, accelerator complex, and experimental facilities




New storage ring PETRA IV (6 GeV, 20 pm emittance)
New booster synchrotoron DESY IV (6 GeV)
Full energy Laser Plasma accelerator (6 GeV)



31 new beamlines and associated laboratories

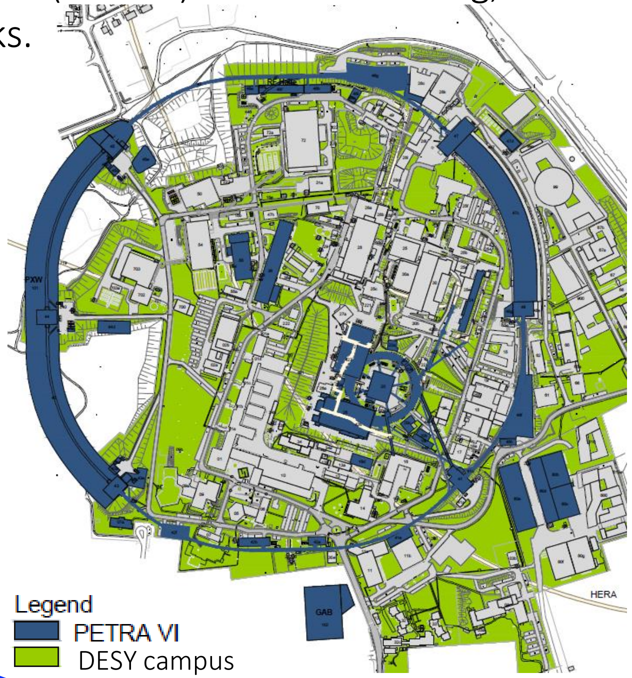
# PETRA-IV

## Buildings/Infrastructure:
## ~700 MEuros

Experimental Hall West, Supply Buildings, RF Hall. Refurbishement of a large number of Buildings

**Industrial needs:**

>70 buildings, Air handling systems, power supply network, IT network, refrigeration plants (13MW) for water cooling, Electronics racks.

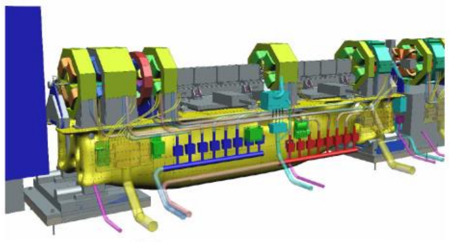


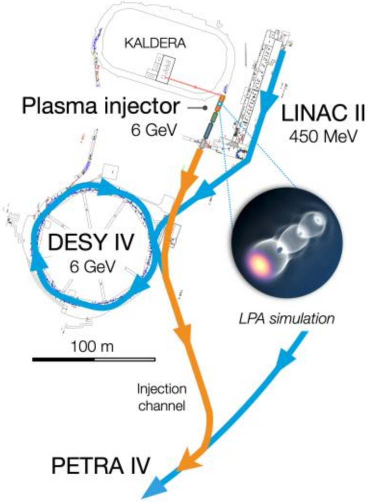

## New Accelerator Structure:
## ~360 MEuros

PETRA IV storage ring, DESY IV Booster synchrotron, Transfer lines, LPA injector

**Industrial needs:**

>3000 magnets, vacuum system (chambers and pumps), 5000 power supplies, RF cavities, ~300 girders, diagnostics.






**15 MEuros pre-project 2024–2027:**

Plasma injector prototype for DESY II/ PETRA III

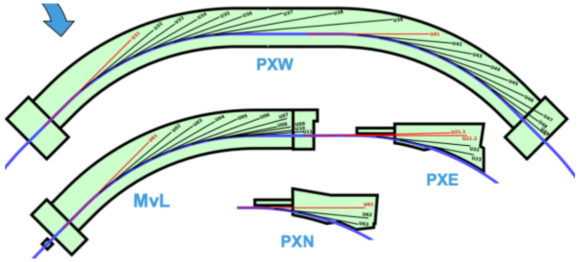
→ Demonstrate full technology chain

## Experiments:
## ~320 Meuros

16 new beamlines, 15 refurbished beam lines

**Industrial needs:**

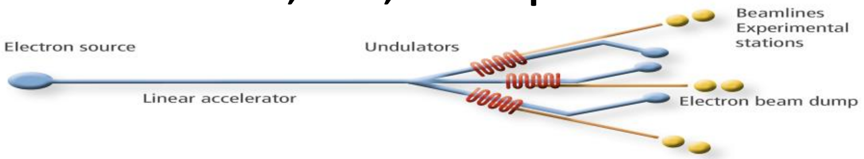
> 100 hutches,
monochromaters,
mirror systems, KB systems,
pixel detectors, endstations,
445 BL control electronics elements,
IT Hardware



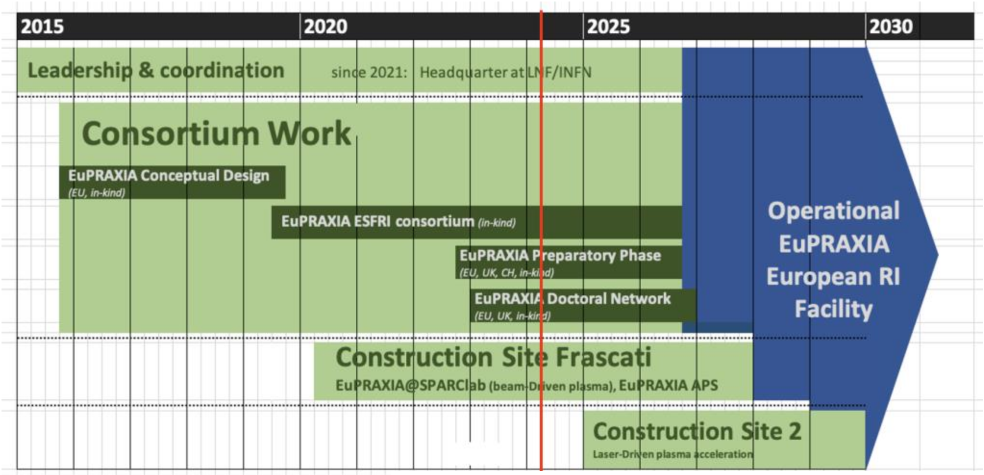
# EuPRAXIA

## European Plasma Research Accelerator with eXcellence in Applications

EuPRAXIA is a design and an ESFRI project for a distributed European Research Infrastructure **based on novel plasma-acceleration concepts, building two plasma-driven Free Electron Lasers, FELs, in Europe**.



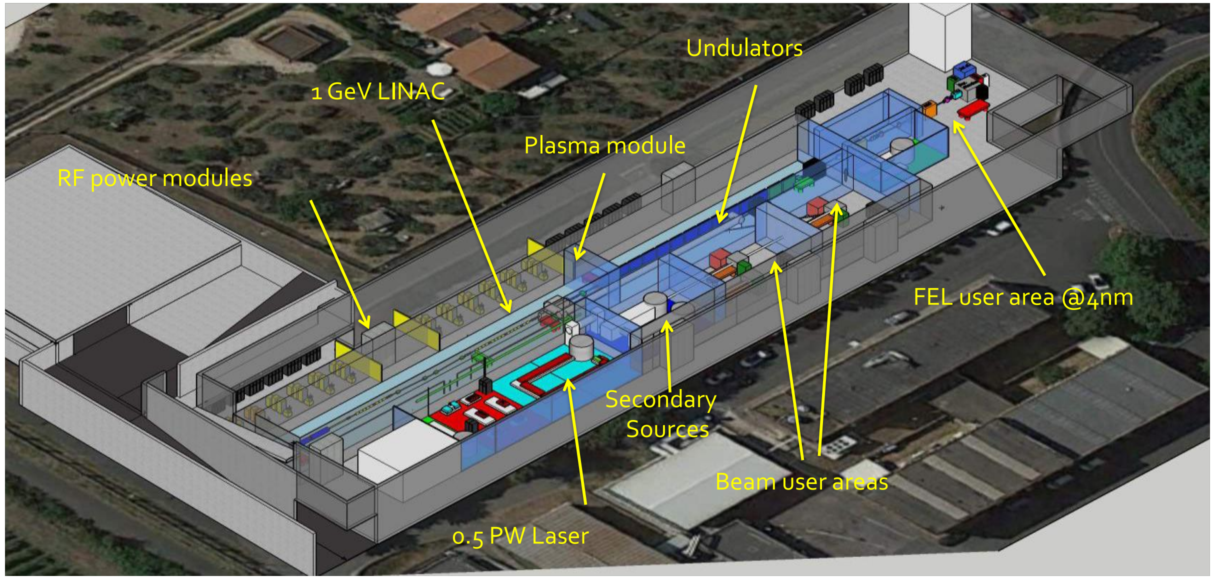

- Site 1: EuPRAXIA FEL in Frascati LNF-INFN (beam-driven) is sufficiently funding
- Site 2: EuPRAXIA FEL (laser-driven)will be selected in next 18 months, among 4 excellent candidate sites




Today: 54 institutes in Consortia

### EuPRAXIA@SparcLAB in Frascati, Budget today: 139 MEuros

→ Construction has started
→ First FEL user operation in 2028.
Combining X-band linac with beam-driven plasma acceleration




**Industrial needs:**
Undulators, high power high-frequency RF sources, magnets, HV-generator, vacuum system.
**Laser systems: efficient kHz** laser driver modules for plasma acceleration

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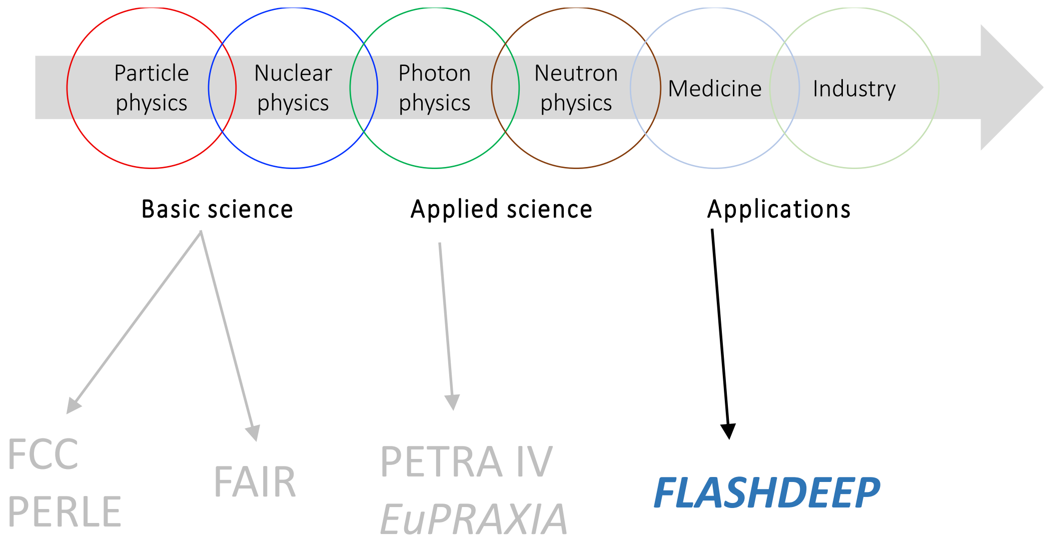
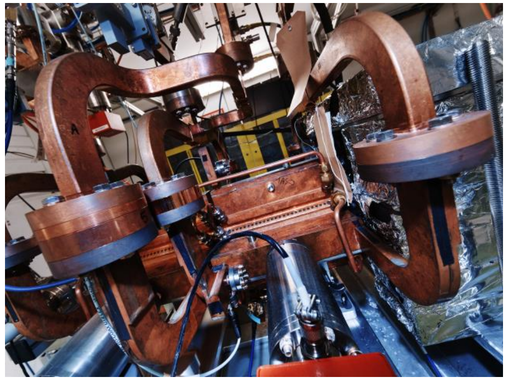
2. Examples from the three accelerator domains



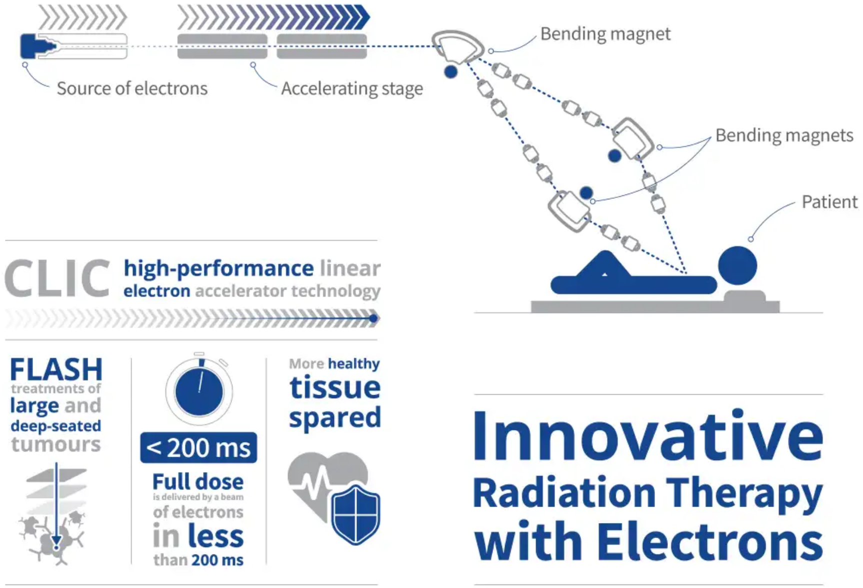

3. Lessons learnt from HiLumi-LHC

# Medical Accelerators

VHEE: Very High Energy Electrons: 100 MeV range
FLASH effect: ultra-high dose rate (above 100 Gy/s) radiation delivery
Many existing electron linac facilities used to investigate VHEE/FLASH Radio Therapy



**CERN, THERYQ and CHUV (University Hospital of Lausanne)** collaborate on the realization of a **clinical facility** for the treatment of larger, deep-seated tumors bye a VHEE beam in FLASH conditions.
➔ Based on CLIC X-band high-gradient acceleration technology




→ **First clinical tests in 1-2 years**.

Industrial needs:
High-power, high-frequency RF sources (modulators and klystrons), high-gradient accelerating cavities, compact magnets, special beam delivery systems and UHDR dosimetry, FLASH-RT treatment planning, fast control and safety systems…

→ **If successful the facility may open the way for many future VHEE/FLASH facilities**

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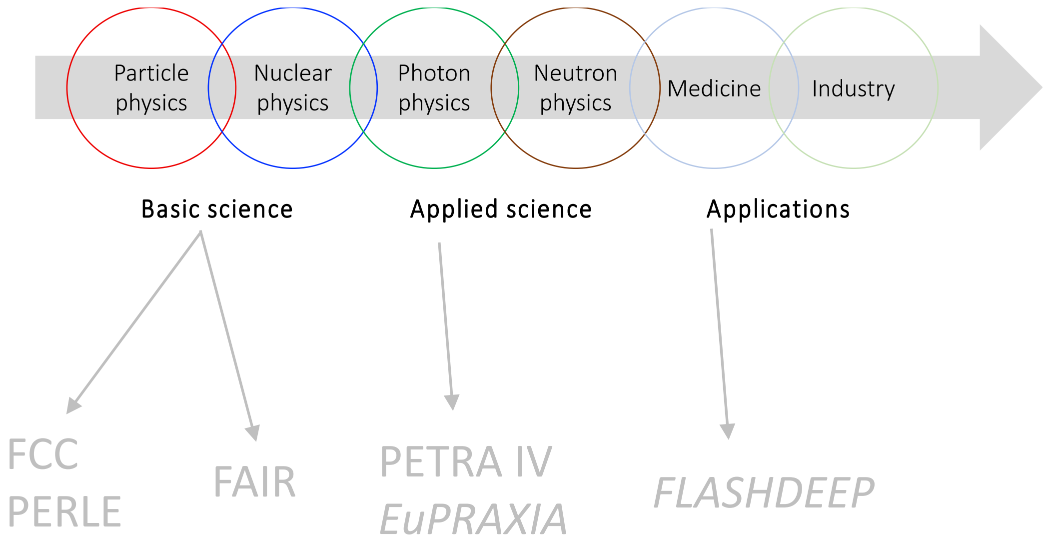
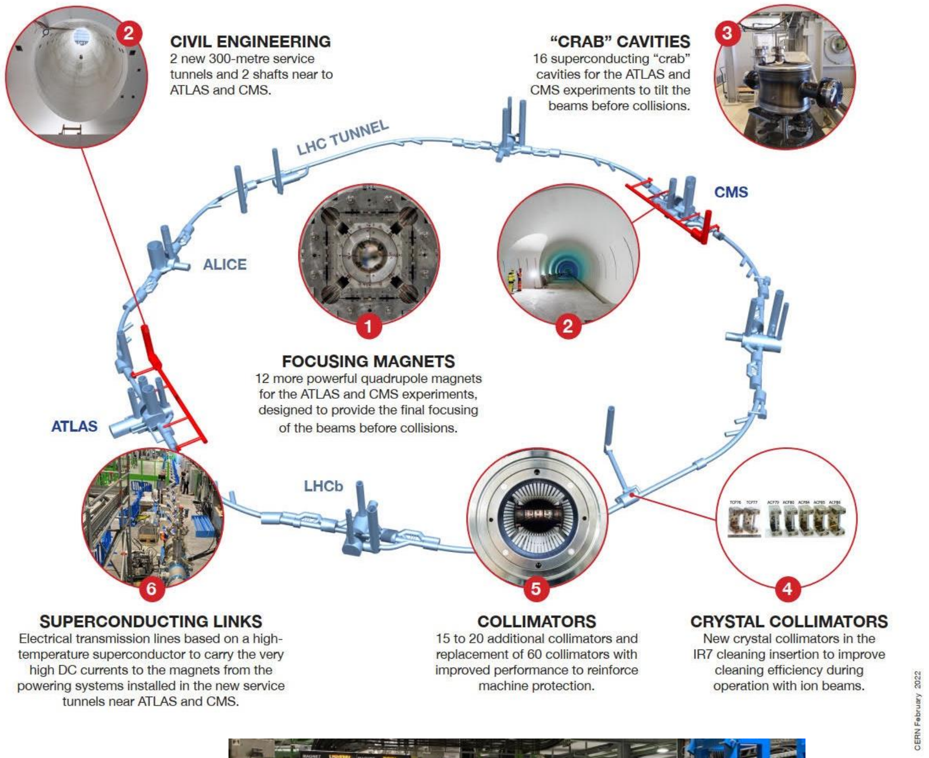



3. Lessons learnt from HiLumi-LHC

# What We have Learnt from HiLumi LHC

## High Luminosity upgrade: increase the integrated luminosity by a factor of 10

2011: EU funded HiLumi-LHC design study
2016: Approval of HiLumi-LHC project
2023: Start of surface installation
2026: Start of tunnel installation
2029: HiLumi-LHC operation




**Total budget: 1.1 BCHF.**
**Today ~80% committed**
70% of total budget is committed in industrial contracts
More than 10000 orders and contracts signed in total

**Lessons learnt:**

- **Sufficient time for tendering** should be accommodated in the planning
- **Challenge for small series production** (less attractive, less interest)
- Open the Market – **Single Tenders are a huge risk** (Organizational strategy)
- **Changes** during series production **not easy** to handle (delays, extra costs…)
- **Visits** during the Contract execution are fundamental
- **Site Acceptance Tests** (cross-check quality of critical sub-components upon reception)
- **Timeline** in industry ≠ Timeline CERN Projects

# Summary

1. Accelerator projects with overall budget of many billion Euros are planned in Europe.
2. These projects touch many areas including fundamental science, applied science, medicine and industry applications.
3. Developments closely with industry is mandatory to achieve the ambitious goals of the accelerator projects.

https://ipac24.org/wp-content/uploads/2024/05/IPAC24-PAPU.pdf

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